

FLAT TRANSDUCER FOR SURFACE ACTUATION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The application is a continuation of co-pending U.S. patent application Ser. No. 16/418,745, filed May 21, 2019, which is incorporated herein by reference.

FIELD

[0002] An aspect of the invention is directed to flat transducer for surface actuation, more specifically, a flat transducer having a suspension system incorporated within the magnet assembly to reduce an overall thickness. Other aspects are also described and claimed.

BACKGROUND

[0003] In modern consumer electronics, audio capability is playing an increasingly larger role as improvements in digital audio signal processing and audio content delivery continue to happen. In this aspect, there is a wide range of consumer electronics devices that can benefit from improved audio performance. For instance, smart phones include, for example, electro-acoustic transducers such as speakers that can benefit from improved audio performance. Smart phones, however, do not have sufficient space to house transducers, or other actuators, having a relatively large z-height or thickness. This is also true for some portable personal computers such as laptop, notebook, and tablet computers, and, to a lesser extent, desktop personal computers with built-in transducers. Such size constraints, however, can pose a challenge since the transducers or actuators incorporated within these devices may include a moving coil motor made up of a stack-up of various components. For example, the moving coil motor may include a diaphragm, voice coil and magnet assembly positioned within a frame, all of which add to the overall z-height of the assembly.

SUMMARY

[0004] An aspect of the disclosure is directed to a thin transducer that serves as an actuator for the surface to which it is connected to. Such a transducer may also be referred to herein as an electro-dynamic transducer or a shaker. A shaker (or surface actuator) may be used to actuate (e.g., vibrates) a surface it is connected to and use the structure as its radiating surface. Shakers may depend on the inertia of the magnet motor system for their performance. The higher the inertia and the force, which is generated by the magnet motor, the more effective they become in application. Given different working orientations, heavy magnet mass, however, develops a static load over the suspension due to gravity or acceleration of the device and may force the suspension to bend in an axis other than parallel to the symmetry axis of the transducer. Any suspension should constrain the movement of the magnet motor, only in the symmetry axis direction, and should not allow relative motion to occur between any of two points over the magnet. To accomplish this, a suspension having a high stiffness to prevent the magnet motor from moving in directions other than parallel to the symmetry axis may be used. Such suspensions, however, are positioned in the excursion space between the moving mass (e.g., magnet) and the actuating surface, which can increase non-linear behavior of the

suspension since it must collapse completely to allow maximum excursion. In addition, rigid suspension members result in high resonance frequencies for a given mass, which can adversely affect the performance of the assembly.

[0005] The transducer assembly disclosed herein solves some of the previously discussed challenges by incorporating the suspension assembly inside the magnet assembly stack-up, and in such a way that it does not increase the z-height of the overall assembly. For example, the suspension assembly may include a number of suspension elements or members, such as springs (e.g., leaf springs) arranged around the perimeter of the magnet assembly, as opposed to extending from a top or bottom side of the magnet assembly, so that they do not add to the z-height. In addition to a reduced z-height, rocking mode prevention may be achieved by adding suspension elements (e.g., leaf springs) to a center opening of the magnet assembly. The suspension elements in the center opening may be oriented at an approximately 90 (+15) degree angle to the diagonals of the magnet assembly. One advantage to rotating the inner suspension elements relative to the outer suspension elements as described is an increased stiffness of the suspension system in the plane which is parallel to the radiating surface. In addition, the suspension elements may have a width dimension which also helps with rocking mode prevention. For example, the suspension elements may have a width dimension that covers up to $\frac{1}{12}$ th of the side of the magnet assembly to which it is attached. In addition, the proposed suspension assembly enables the magnet motor assembly thickness to be used by the suspension assembly, giving more room for the suspension geometry. Still further, the suspension assembly disclosed herein does not have to collapse completely to allow the maximum excursion of the magnet motor assembly. This, in turn, improves the linear operation range of the suspension assembly. Moreover, the suspension member (e.g., spring) can be made larger than the excursion space (e.g. greater z-height), enabling the suspension to be more flexible and reach a lower resonance frequency with the moving mass (e.g., magnet assembly) for a given fixed thickness. In addition, in the case of a leaf spring suspension member, the leaf spring provides high rigidity within the parallel surface to the radiating surface, and protects the voice coil from getting into contact with metal components of the magnet. In addition, the combined two suspension system may provide additional advantages, including but not limited to, minimizing bending of the magnet assembly when the device is held in a vertical orientation, and may be effective towards high acceleration values which can be caused by drop.

[0006] More specifically, aspects of the disclosure include a transducer assembly having a stiffener plate with a first side and a second side, and a voice coil coupled to the second side of the stiffener plate. A magnet assembly is positioned along the second side of the stiffener, the magnet assembly operable to produce a magnetic field that causes a movement of the magnet assembly relative to the voice coil. In addition, a spring suspends the magnet assembly from the stiffener plate such that the movement of the magnet assembly drives a movement of the stiffener plate. The spring may be arranged around a perimeter of the magnet assembly and include a first extension member attached to the second side of the stiffener plate and a second extension member attached to a bottom side of the magnet assembly, which faces away from second side of the stiffener plate. The